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Title Page

Does overstuffing of the patellofemoral joint in total knee arthroplasty have a significant effect on post-operative outcomes?

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Abstract

Background and purpose

There is ongoing debate in the literature as to whether or not patellofemoral joint overstuffing has a clinically significant effect on post-operative outcomes following total knee arthroplasty (TKA). This study investigates the effect of patellofemoral joint overstuffing on patient-reported outcomes using novel methods of radiographic measurement.

Patients and methods

The study population consisted of a prospective cohort of 266 patients receiving a Triathlon® (Stryker, Kalamazoo, MI, US) TKA between 2006 and 2009. Participants completed the Western Ontario and McMasters osteoarthritis index (WOMAC) questionnaire pre-operatively and at 12 months post-operatively. Pre- and post-operative radiographic measurements were taken according to a defined protocol to assess for patellofemoral overstuffing. Measurement reproducibility was assessed using inter-observer intraclass correlation coefficients. Associations between radiographic measurements and patient-reported outcomes were analyzed using linear regression analysis.

Results

One hundred and seven patients had adequate images and were included in the analysis for this study. Three different radiographic measurements were used to identify patellofemoral overstuffing all with good intra- and inter-observer reliability. There was no association identified between combined (patella and trochlea) patellofemoral

overstuffing measurements and WOMAC scores. However a statistically significant association was identified between an increase in anterior trochlear offset and worse knee pain and function scores ($p < 0.05$).

Interpretation

There is no identifiable association between true patellofemoral overstuffing and clinical outcome however there is a small association with the anterior trochlear offset though further studies are warranted to confirm the clinical significance of this finding.

Key words: Patellofemoral overstuffing; Anterior Trochlear Offset; Total Knee Arthroplasty; Patient-Reported Outcome Measures

Introduction

Total knee arthroplasty (TKA) is often a successful operation for patients with severe knee osteoarthritis. Despite this, a systematic review has shown that between 10 and 34% of patients have an unfavorable long-term pain outcome [1]. Persistent pain is multifactorial [2] and one potential cause is the alteration in patellofemoral joint biomechanics [3] including patellofemoral overstuffing which has been shown to increase patellofemoral contact forces [4]. Patellofemoral overstuffing is caused by a mismatch between the amount of bone resected from the anterior femur and the thickness of the prosthesis replacing it. This can be compounded by inadequate patellar resection if patellar resurfacing is performed concurrently. It is possible that overstuffing results in accelerated polyethylene wear and loosening as well as having an adverse influence on post-operative flexion [5].

There are a number of studies published in the literature assessing the effect of patella thickness and patellofemoral overstuffing on postoperative outcomes [6] [7] [8] [9] [10] [11] [12] [13]. Early studies [6] [7] [8] [9] [10] suggested that an increase in dimensions led to an increase in post-operative patellofemoral contact forces and a reduction in knee flexion however, larger subsequent studies [11] [12] [13] showed no clinically significant difference in post-operative outcomes including range of movement, need for intraoperative lateral release (to improve patellar tracking) and pain scores. There are several limitations to these studies however which may well have affected their findings. These include the lack of correction for magnification differences in the radiographic measurements taken [12], not including all measurements for overstuffing (such as anterior patella displacement) [13], not including both resurfaced and unresurfaced

patients in the cohorts [13] as well as the fact that the data was collected retrospectively [11] [12] [13].

The rationale for this study was to identify a more reliable and reproducible radiographic method of measurement for patellofemoral overstuffing as well as answering the question as to whether or not patellofemoral overstuffing has an effect on postoperative patient-reported outcome measures (PROMs) following TKA.

2

Patients and Methods

2.1

Patients

The study population was a cohort of patients receiving a Triathlon® (Stryker, Kalamazoo, MI, US) TKA between 2006 and 2009. These patients were recruited to a prospective single center cohort study in the UK assessing the outcomes and survivorship of the Triathlon knee replacement [14]. Inclusion criteria for the cohort study consisted of patients undergoing primary Triathlon TKA for osteoarthritis or rheumatoid arthritis. Exclusion criteria comprised patients unwilling to provide informed consent, patients with revision surgery or an inability to complete questionnaires for cognitive or physical reasons or language barriers. Patients were further excluded from our current analysis if they had rheumatoid arthritis or if they did not have satisfactory radiographs available for analysis (see Figure A).

Anaesthetic management, operative approach, soft tissue release and resurfacing of the patella were at the discretion of the operating surgeon. The implants were cemented and either cruciate-retaining or posterior stabilized. Standard post-operative

rehabilitation protocols were followed. Pre-operative and post-operative follow-up data, including routinely taken radiographs, were prospectively collected as part of the cohort study. Full ethical approval was obtained on 07/09/2006 for the cohort study from South West – Central Bristol REC (reference number 06/Q2002/80) and all patients provided informed, written consent.

2.2

Data collection

Data was collected prospectively including baseline demographic details and preoperative knee scores. To assess self-reported knee function, pain and stiffness, the Western Ontario and McMasters osteoarthritis index (WOMAC) questionnaire was used [15]. This questionnaire assesses the severity of pain when performing five activities, the degree of functional limitations during 17 activities and the degree of stiffness at two time points (after first walking and later in the day). The pain, function and stiffness scores were transformed to 0-100 scales, with 100 indicating no pain/functional difficulty/stiffness and 0 indicating extreme pain/functional difficulty/stiffness. The WOMAC was completed preoperatively and at 12 months post-operatively.

2.3

Radiographic measurements

Three different radiographic measurements for patellofemoral overstuffing were defined. These were the Teardrop Distance Ratio (TDR), the Medial Patellofemoral Ligament Distance Ratio (MPFLD) and the Anterior Trochlear Offset Ratio (ATOR). Two out of the three measurements used (TDR and MPFLD) were designed to include

anterior displacement of the patella as well as an increase in the anterior dimensions of the distal femur. Previous studies have demonstrated a relationship between overstuffing and retinacular tension, including the length of the MPFL [16]. Ghosh et al [16] assessed the effect of overstuffing the patellofemoral joint on the extensor retinaculum of the knee. They found that overstuffing of the patellofemoral joint by 4mm resulted in a significant overall increase in length of the medial patellofemoral ligament (MPFL) at all angles of knee extension. Therefore by using a measurement that approximates to the length of the MPFL, we postulated that it may be possible to assess more accurately for patellofemoral overstuffing than by using the measurement methodology in the currently available studies. The radiographic landmarks of the femoral origin of the MPFL have been identified [17] and therefore were used to help create reproducible radiographic measurements, TDR and MPFLD, that would approximate to the length of the MPFL and hence identify changes in the anterior dimensions of the distal femur as well as anterior displacement of the patella. All measurements taken in this study were presented as a proportion of the femoral shaft diameter in order to control for magnification differences between radiographs, which has not been done consistently in previous studies. One previous study [12] demonstrated a potential association, albeit small, between anterior femoral offset and a decrease in post-operative knee scores and therefore a variation of this, presented as a ratio of the femoral shaft diameter to correct for magnification, was used in this study (ATOR).

Pre- and post-operative radiographic measurements were taken according to a defined protocol (see Figures 2 and 3). The latest available preoperative radiograph was used. Radiographs taken at a minimum of six weeks post-operatively (to avoid the potential for artificially elevated measurements secondary to a post-operative haemarthrosis) and a maximum of 12 months post-operatively were used. All radiographic evaluations were performed by the same reviewer and were completed blindly with regard to the clinical outcome. Only true lateral radiographs with minimal rotation were used for assessment where the posterior borders of the femoral condyles or femoral prosthesis (as well as the pegs of a cruciate-retaining implant) superimposed with no separation (see Figure D for an example of an excluded radiograph due to poor rotation).

2.4

Statistical analysis

Measurement reproducibility was assessed by the inter-observer intraclass correlation coefficient (ICC), comparing results of measurements on a random selection of 10 radiographs between two observers, and intra-observer ICC using the same radiographs comparing repeat measurements by the same observer two weeks apart. The ICCs were calculated using SPSS software package 19.0 (SPSS Inc., Chicago, Illinois).

Linear regression analysis was performed using Stata SE 13.1. The outcomes were post-operative WOMAC pain, function and stiffness scores at 12 months. The prognostic factors were patient sex, age, side of operation and preoperative values for WOMAC pain, stiffness and function. Significance was determined with a P-value of <0.05.

Results

There were 266 patients recruited to the original cohort study. Out of these, 159 were excluded from this study. The main reason for exclusion was the lack of available or satisfactory radiographs for analysis (Figure A).

A total of 107 patients were therefore included in the study. There were a higher percentage of female patients than male (55:45). The mean age of the participants was 68.9 (SD, 9.6). The mean height of the patients was 167.3 cm (SD, 10.7) and mean weight 85.7 Kg (SD, 18.6) with a mean Body Mass Index (BMI) of 30.8 (range 15.0 to 44.9). Ninety-six patients received cruciate-retaining and eleven posterior-stabilized implants. Seventy-nine patients underwent patellar resurfacing concurrently and 28 patients did not.

Intra- and inter-observer correlation coefficients for all measurements were greater than 0.8 (Table A). Mean WOMAC scores increased at 12 months post-operatively as compared to pre-operatively by 38.7, 27.5 and 25.3 points for pain, function and stiffness respectively (Table B). Overstuffing is defined as TDR, MPFLD and ATOR values greater than one. The magnitude of overstuffing seen is relatively small when TDR and MPFLD are used with an upper limit of 112.9% and 118.1% (expressed as a percentage of preoperative values). However, when ATOR is used larger magnitudes are identified (with a maximum of 299% seen). Linear regression analyses (Tables C to E) demonstrated a significant association between an increase in ATOR and a reduction in WOMAC pain ($p=0.039$) and WOMAC function ($p=0.036$) scores one year post-operatively when adjusted for patient age, sex, side of operation and pre-operative WOMAC score. No association was found between an increase in ATOR and WOMAC

stiffness score and no significant associations were identified between changes in TDR or MPFLD and any of the post-operative WOMAC scores.

4

Discussion

This study shows that an increase in ATOR is associated with worse patient reported pain and function at 12 months after TKA. The two measurements for patellofemoral overstuffing, TDR and MPFLD, did not show any statistically significant association with post-operative WOMAC score although the changes seen were relatively small (TDR ranging from 83.0% to 112.9% and MPFLD from 88.3% to 118.1%, expressed as a percentage of the preoperative measurement). All three measurements for overstuffing proved reproducible, particularly the ATOR with inter- and intra-observer correlation coefficients greater than 0.9 (Table A).

The results of this study suggest that doubling the pre-operative ATOR would cause an approximate 8-point reduction in both the WOMAC pain and function scores. Minimally important clinical differences for the WOMAC score after TKA have been quoted as being 15 [18] and therefore this study would suggest that very large changes in ATOR (three times the preoperative value) are required to cause clinically important changes in post-operative WOMAC score, which in practice would only be possible in those patients with a very low pre-operative ATOR.

Neither of the other measurements, designed to assess for true patellofemoral overstuffing, demonstrated a significant association with post-operative PROMs. This may be due to the likely increase in variability between these measurements and true overstuffing, as it is possible their accuracy was more sensitive to other variables such

as the degree of knee flexion when the radiograph was taken. It is also possible that, as suggested by a number of other studies, patellar thickness is less important [11] [19] [20] or indeed that there is no association with true overstuffing, despite widespread clinical opinion to the contrary.

Although the clinical importance of the changes seen is difficult to quantify, this study does suggest that patients may be more sensitive to an increase in their anterior trochlear offset as compared to an overall increase in their anteroposterior dimensions and associated patellofemoral overstuffing. This information could be very useful to orthopaedic surgeons as there is a very large variation between patients in the degree of anterior trochlear offset that they have which is not necessarily related to the overall size of the distal femur. Sizing a Triathlon TKA is done using a stylus placed against the anterior cortex of the distal femur and does not take into consideration the anterior trochlear offset. As well as this, the Triathlon TKA is a posterior referenced system and therefore sizing varies anteriorly with a constant posterior cut. These factors can lead to considerable variability in the thickness of bone removed anteriorly as compared to the thickness of the femoral component replacing it and hence to large changes in the anterior trochlear offset. With the knowledge that this could have a significant effect on post-operative outcomes the surgeon could take more care ensuring that an adequate amount of bone is removed during the anterior femoral resection in order that the anterior trochlear offset is not inadvertently increased following implant insertion. This study would also suggest that an anterior referenced TKA system, where a constant anterior resection is made with a more variable posterior resection, may have some advantages, although the importance of posterior over- or under-stuffing was not assessed in this study.

All the outcome data in this study was collected prospectively as part of a prospective cohort study with all the radiographic measurements being done retrospectively. The potential for introducing bias was eliminated by blinding the reviewer to the outcome scores when performing the radiographic measurements. The main limitation of this study is the number of exclusions necessary from the original cohort of patients. Out of the 266 patients recruited into the cohort study, only 107 were included in this analysis, the majority being excluded due to lack of available or unsatisfactory radiographs within the required timeframe (6 weeks to 12 months post-operatively) for analysis. Despite this however, this is one of the largest studies available assessing for true patellofemoral overstuffing, with prospectively collected outcome data (at set time points) and reproducible measurement techniques. We believe that this study has generalizability to other populations undergoing knee arthroplasty, using a posterior referenced implant, for osteoarthritis as the age, BMI and gender of our cohort reflect that of the populations reported in the national registries [21] [22] [23].

5

Conclusions

In conclusion, there is no identifiable association between true patellofemoral overstuffing and clinical outcome in this study however there does appear to be a small statistically significant association with the anterior trochlear offset with worse post-operative knee pain and function scores though further studies are warranted to confirm the clinical significance of this finding.

Tables and Figures

Table A- Intraclass correlation coefficients

| Measurement | Intra-observer correlation | Inter-observer correlation |
|--------------------|-----------------------------------|-----------------------------------|
| TDR | 0.974 | 0.860 |
| MPFLD | 0.966 | 0.878 |
| ATOR | 0.968 | 0.926 |

Table B- Descriptive statistics for pre- and post-operative WOMAC pain, function and stiffness scores, and mean change in TDR, MPFLD and ATOR pre- to post-operatively

| Measure | n | Mean (SD) | Percentiles | | |
|------------------------------------------|----------|------------------|--------------------|-----------|-----------|
| | | | 25 | 50 | 75 |
| WOMAC pain score (pre-op) | 104 | 41.7 (17.9) | 30 | 40 | 52.5 |
| WOMAC function score (pre-op) | 102 | 46.5 (16.7) | 33.8 | 45.6 | 55.9 |
| WOMAC stiffness score (pre-op) | 104 | 43.4 (23.0) | 25 | 37.5 | 50 |
| WOMAC pain score (12 months) | 98 | 80.4 (20.6) | 70 | 85 | 100 |
| WOMAC function score (12 months) | 98 | 74.0 (20.6) | 60.3 | 77.2 | 92.6 |
| WOMAC stiffness score (12 months) | 93 | 68.7 (22.9) | 50 | 75 | 87.5 |
| Change in TDR | 107 | 1.008 (0.078) | 0.9554 | 1.004 | 1.043 |
| Change in MPFLD | 107 | 1.003 (0.058) | 0.965 | 1.001 | 1.036 |
| Change in ATOR | 107 | 1.123 (0.570) | 0.696 | 0.947 | 1.429 |

WOMAC, Western Ontario McMaster Universities Osteoarthritis Index; TDR, teardrop distance ratio; MPFLD, medial patellofemoral ligament distance ratio; ATOR, anterior trochlear offset ratio; n, number of patients with completed scores; SD, standard deviation

Table C- Linear regressions between WOMAC pain score (12 months) and change in TDR, MPFLD and ATOR adjusted for age, sex, side of operation and baseline WOMAC score

| WOMAC pain (12 months) | Regression Coefficient | 95% Confidence intervals | P-value |
|-------------------------------|-------------------------------|---------------------------------|----------------|
| Change in TDR | -11.89 | -69.21 to 45.44 | 0.681 |
| Change in MPFLD | -48.32 | -122.36 to 25.71 | 0.198 |
| Change in ATOR | -8.14 | -15.86 to -0.42 | 0.039 |

Table D- Linear regressions between WOMAC function score (12 months) and change in TDR, MPFLD and ATOR adjusted for age, sex, side of operation and baseline WOMAC score

| WOMAC function (12 months) | Regression Coefficient | 95% Confidence intervals | P-value |
|-----------------------------------|-------------------------------|---------------------------------|----------------|
| Change in TDR | -4.85 | -59.32 to 49.61 | 0.860 |
| Change in MPFLD | -38.24 | -108.90 to 32.42 | 0.285 |
| Change in ATOR | -7.75 | -14.98 to -0.53 | 0.036 |

Table E- Linear regressions between WOMAC stiffness score (12 months) and change in TDR, MPFLD and ATOR adjusted for age, sex, side of operation and baseline WOMAC score

| WOMAC stiffness (12 months) | Regression Coefficient | 95% Confidence intervals | P value |
|------------------------------------|-------------------------------|---------------------------------|----------------|
| Change in TDR | 7.35 | -55.52 to 70.22 | 0.817 |
| Change in MPFLD | -8.54 | -90.25 to 73.17 | 0.836 |
| Change in ATOR | -5.75 | -14.53 to 3.04 | 0.197 |

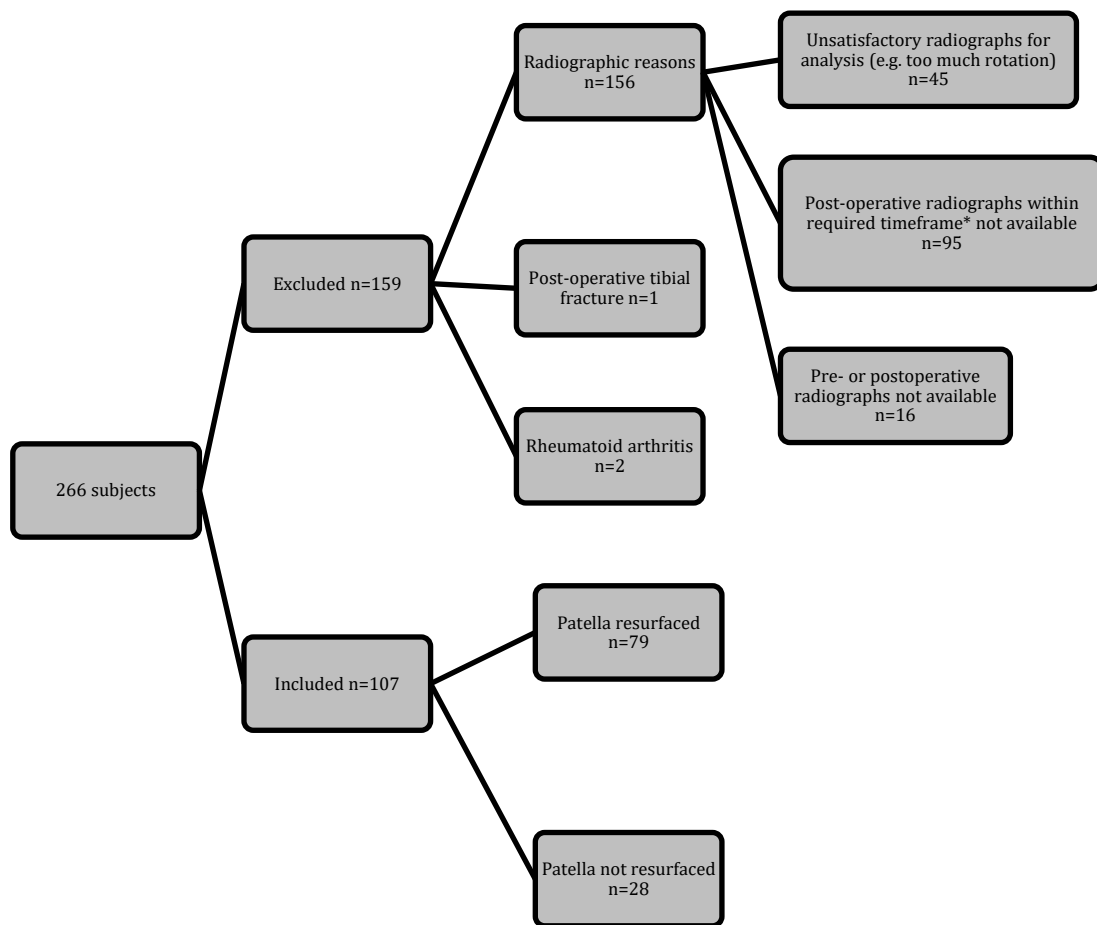


Figure A- Flow diagram illustrating the subject inclusions/exclusions. *Six weeks to 12 months post-operatively

Steps:

1. Draw line along anterior cortex of femur- anterior cortical line
2. Draw a line parallel to this and then place along posterior cortex of femur (best fit)
3. Measure perpendicular distance between 2 lines to give measurement of shaft diameter (see Figure C.1)
4. Draw line between superior and inferior poles of patella- patella line (see Figure C.2)
5. Measure distance from most posterior aspect of teardrop (Figure C.3) to anterior surface of patella (with the line bisecting the patella line halfway along its length) to give the teardrop distance (TD)- divide this distance by the shaft diameter to give the tear drop distance ratio (TDR)- see Figure C.4.
6. Measure the distance from the MPFL femoral origin (see Figure C.5) to anterior surface of patella (with the line bisecting the patella line halfway along its length) to give the MPFL distance- divide this distance by the shaft diameter to give the MPFL distance ratio (MPFLD)- see Figure C.6
7. Measure anterior offset of distal femur- perpendicular distance between anterior cortical line and most anterior part of femoral component. Divide this distance by the shaft diameter to give the anterior trochlear offset ratio (ATOR)- see Figure C.7
8. Overstuffing is determined by dividing the post-operative values by the preoperative values and defined as a value >1

Figure B- Radiograph measurement protocol



Figure C.1- Shaft diameter



Figure C.2- Patella line



Figure C.3- Identification of teardrop (most posterior aspect of Blumensaat's line)



Figure C.4- Teardrop distance. Teardrop distance ratio (TDR)= teardrop distance/shaft diameter

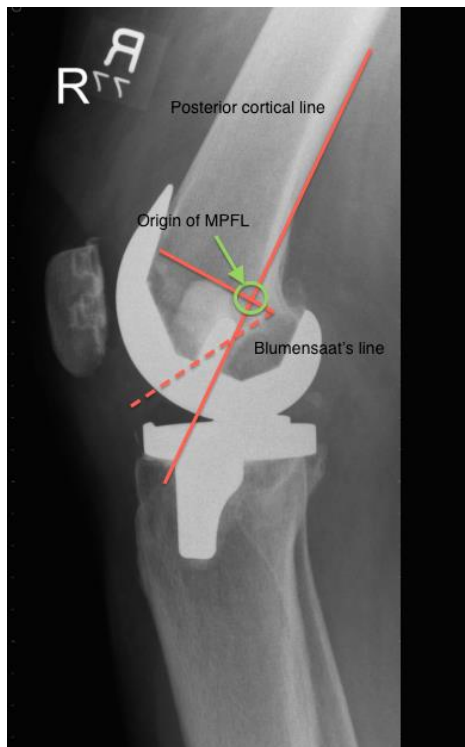


Figure C.5- Identification of MPFL femoral origin:

Draw a line along the posterior cortex of the femur (posterior cortical line) and then another perpendicular to this starting at the most posterior aspect of Blumensaat's line. The point at which this line bisects the posterior cortical line is the approximate femoral origin of the MPFL



Figure C.6- MPFL distance. MPFL distance ratio (MPFLD)= MPFL distance/shaft diameter



Figure C.7- Anterior offset distance. Anterior trochlear offset ratio (ATOR)= Anterior offset distance/shaft diameter

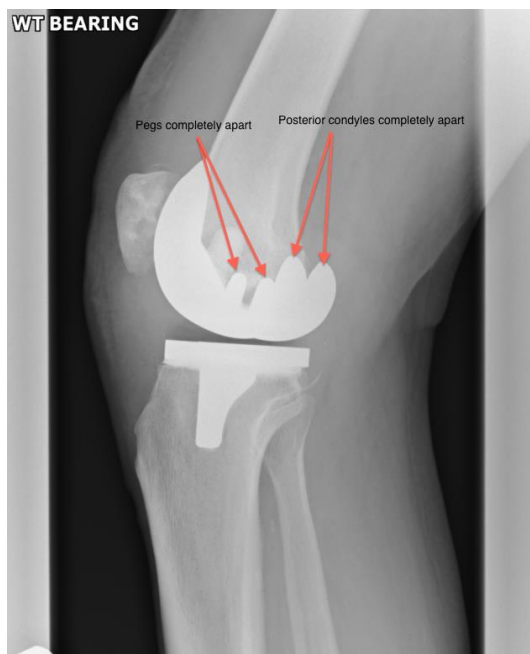


Figure D- Example of poor rotation

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